Lust

AN EVALUATION OF A METHOD FOR USE IN DETERMINING RELATIVE FUSIFORM RUST RESISTANCE IN LOBLOLLY AND SLASH PINE FAMILIES

FOREST TREE RESISTANCE TESTING FACILITY
REPORT NUMBER 1
U.S. DEPARTMENT OF AGRICULTURE
U.S. FOREST SERVICE
STATE AND PRIVATE FORESTRY
SOUTHEASTERN AREA
ASHEVILLE, NORTH CAROLINA

COVER PHOTOS:
FUSIFORM RUST DAMAGE

AN EVALUATION OF A METHOD FOR USE IN DETERMINING RELATIVE FUSIFORM RUST RESISTANCE IN LOBLOLLY AND SLASH PINE FAMILIES

By

Peter P. Laird, John L. Knighten, and Robert L. Wolfe

ABSTRACT

The water suspension spray technique has been found to be adaptable as a method to be used in screening for rust resistance in loblolly and slash pine seedlings. This technique is currently being further refined and improved. Operational testing has already begun on a pilot test basis and it is hoped that a full scale rust resistance testing facility will be initiated by the fall of 1975.

INTRODUCTION

Importance of the Disease

Fusiform rust, caused by *Cronartium fusiforme* Hedgc. and Hunt, is widely recognized as the South's most destructive forest disease. Two of the most important species in the South's rapidly expanding forest economy, loblolly (*Pinus taeda* L.) and slash (*P. elliottii* var. *elliottii* Engelm.) pines are severely attacked.

Powers (1969) estimated that losses in growth of usable timber attributed to fusiform rust approximates 280,000,000 board feet per year. Lewis and Cowling (1970) used 1970 market prices to calculate that loss of this much timber would result in a loss of ten million dollars on the stump and two hundred and fifty million in finished pulp or other wood products.

Historically, fusiform rust has not always been a serious problem in the South. In the 1920's the fungus and the disease were of interest only to mycologists and forest pathologists. Only in the 1950's did it become readily apparent that fusiform rust was rapidly becoming our most serious forest disease problem.

Recent surveys in 8- to 12-year-old plantations in Georgia (Roth and McComb, 1971); Florida (Roth and Chellman, 1971); South Carolina (Roth and Graham, 1971); Arkansas (Roth and Tiner, 1971); Louisiana (Roth and Nachod, 1971); Mississippi (Roth and Echols, 1971); and Alabama (Phelps et al, 1972) revealed fusiform rust incidence is widespread and severe in certain substantial areas. Infection in Georgia is extreme in both loblolly and slash pine plantations, much of the state being more than 50 percent infected. The same is true for the lower two thirds of South Carolina. Rust incidence in the lower half of Alabama and Mississippi is also high (greater than 50 percent). Only the northern tier of counties in Florida had severe infection in slash plantations. Relatively slight rust incidence was observed in Arkansas. High infection pockets were found scattered among areas of low infection through most of Louisiana's pine type.

In general, the areas of high infection mentioned above had only non-significant amounts of rust prior to 1950. This increase in rust incidence has been attributed to many factors. Among these are high grade logging of original forests (Borlaug, 1972), widespread planting of infected nursery stock (Hodges, 1962), use of inferior seed (Borlaug, 1972), offsite planting (Lamb, 1937), increased populations of the alternate oak host due to the suppression of wild fires (USDA, 1958), intensive management practices such as fertilization (Boggess and Stalelin, 1948), and cultivation (Bathis and Anderson, 1944). Perhaps the most significant factor, however, is the huge increase in host type due to widespread planting of the susceptible loblolly and slash pine hosts in plantations over large acreages throughout the South.

Methods of Control

Although fungicides have been used for control of the disease in nurseries, no effective chemical or silvicultural method exists for controlling the disease in plantations or natural stands. However, it has been repeatedly demonstrated that losses due to the disease can be minimized by the proper application of genetic resistance inherent in both loblolly and slash pines.

Jewell (1959, 1961); Barber (1964); Jewell and Henry (1966); Kinloch and Stonecypher (1969); and Blair (1970) have demonstrated the existence of genetically controlled variation in resistance to fusiform rust, both

between and within the various species of southern pines. Generally, of the four major southern species loblolly and slash are susceptible, shortleaf (*P. echinata* Mill.) is immune, and longleaf (*P. palustris* Mill.) is only moderately susceptible. Of primary interest here is that a high degree of genetically controlled resistance exists in selected loblolly (Wells and Wakeley, 1966; Kinloch and Stonecypher, 1969; and Blair, 1970), and slash pines (Barber, 1964; Jewell and Mallett, 1964; and Goddard and Arnold, 1966).

Presently there is a critical need for rust resistant planting stock in high hazard fusiform rust areas, especially those in South Carolina, Georgia, Alabama, and Mississippi, where incidence of the disease precludes successful pine plantation management.

Background on the Development of a Method for Progeny Testing for Fusiform Rust Resistance

At the present time we know there is genetic resistance to fusiform rust in both loblolly and slash pine. The current primary tasks are to develop a rapid means of identifying genetic sources of resistance and the incorporation of this resistance into superior seed for distribution to landowners. This project is presently concerned only with the first task; the second will be the responsibility of southern tree improvement organizations.

Rapid screening for the identification of resistance is necessarily conducted by testing progenies at the seedling stage. Field tests, although they are essentially the ultimate tests for all tree improvement programs, are insufficient in initial screening program for disease resistance largely due to lack of controls over infection phenomena and length of time required to obtain reliable results.

Many agencies, including the U. S. Forest Service, universities, and private companies have tried their hands at screening for rust resistance, but they all have encountered a variety of problems.

At the 1969 Symposium of the Biology of Rust Resistance in Forest Trees at Moscow, Idaho, Schmidt (1972) reviewed the inoculation techniques used in studies of fusiform rust. Of 12 previous methods employed, all had deficiencies in one or more of the following: control of temperature and/or humidity, control over time of inoculation, control of inoculum density, and ability to rapidly test large numbers of seedlings necessary in a screening program. Control over inoculation density was a constant problem except in techniques limited to individual plants.

At the same Symposium, Patton (1972a and 1972b) emphasized, in his moderators summary of the section dealing with inoculation problems and techniques, that problems in rust evaluation testing are the lack of standardization of inoculum density and the inability to relate quantitatively the host response to inoculum density.

Despite these problems, workers in fusiform rust resistance work realized that the development of a reliable screening method for large quantities of material was mandatory for rapid progress in resistance if selection could be made. By the end of the last decade both of the Forest Service's research stations in the South (Gulfport and Athens) possessing research projects in fusiform rust and the University of Florida's tree improvement program had shifted a considerable proportion of their efforts to development of a valid large scale screening method. At the same time the idea of establishing a centralized facility for testing for fusiform rust resistance, similar to that of the maize program developed by Dr. Borlaug in Mexico (Borlaug, 1964 and 1972) was formulated.

After considerable discussion by scientists working in fusiform rust resistance programs, Lewis and Cowling (1970) formally proposed a centralized testing center. The general conclusion being the standardization and precision necessary for adequate screening could be accomplished at one location under one staff.

The proposal was presented at an informal meeting of parties interested in rust resistance work at International Paper Company, Southlands Experimental Forest near Bainbridge, Georgia, on May 14, 1970. Following this meeting a proposal was prepared and submitted to the Forest Service's Washington Offices of Forest Research and State and Private Forestry.

Early in 1971 a memorandum from the Washington Office notified the Southeastern Area Director for State and Private Forestry and Directors of the Southern and Southeastern Forest Experiment Stations to meet and select a proposal for a "best system" for our testing needs. State and Private Forestry was designated as the responsible agency to develop the testing center.

In May of 1971 the meeting was held in the Area Office in Atlanta, Georgia, with representatives present from the Asheville and Alexandria Zones of Forest Pest Management, the Southern and Southeastern Research Stations, Washington Office, Forest Pest Control, as well as representatives of the Area Office, Forest Pest Management Group. The highlight of that meeting was the unanimity of the group in choosing the Asheville Zone and Bent Creek facilities to conduct immediately an initial evaluation of methodology for possible use in the testing center. That is, a pilot operation would have to be established to determine the most practical, effective, and reliable method to be used in the screening process.

No recommendation was made concerning which inoculating system would be used. Two methods had been included in original proposals sent to Washington. One involved mass inoculation of seedlings in a complex chamber (Dwinell, 1972). The other inoculated only single plants from inoculum prepared in a chamber (Snow, 1968; Snow and Kais, 1972). A new method being developed at the Southeastern Forest Experiment Station in Athens was also discussed. This method involved the application of a suspension of inoculum directly on flats of seedlings. It was agreed that this system was also worthy of consideration and in many ways was the most promising.

In the months immediately following the Atlanta meeting the three methods were scrutinized in detail, and it was decided that the suspended inoculum spray system, even though it contained some unknown facets, was the only one of three that could be practically adapted to a mass screening program. Since it was the most adaptable and was basically sound in plant pathology techniques, it was selected as the basic method to be further improved and pilot tested for implementation into a large scale screening program.

The basic method has been outlined in a Southeastern Station office report (Matthews et al, 1971). Matthews and Rowan (1972) also published information demonstrating successful inoculation of pine seedlings. However, the reliability of the method for use in large scale screening for fusiform rust resistance remained unknown.

OBJECTIVE

The objective of this evaluation was to determine if the suspension spray technique could be used as a reliable method for large scale testing for resistance in slash and loblolly pine seedlings.

GENERAL METHODOLOGY

Once it was determined to test the spray suspension method of inoculation it became obvious that many decisions had to be made in the development of other phases of the method to have a valid test. Complete standardization and precision was required. In our inspection of the various methods previously used in fusiform rust testing, it was found that they differed considerably in the culture of pine and oak, the handling of aeciospores, the production of basidiospores, etc. At the same time we also had our own ideas on how to improve the system.

It was decided that the most ideal way to get the best total testing system together was to incorporate all of the latest and most sophisticated techniques and ideas into one system. The best way to do this was to get a representative committee of workers with experience in testing for fusiform resistance to serve as an advisory committee in the development of the fusiform rust testing center. They would serve not only to advise us of the needs of people who may use such a center, but also to offer any professional and technical advice that may further the development of a testing system to be used in the testing center.

The following members were originally selected in November of 1971 to serve on the committee:

Ellis Cowling (Chairman)	Pathologist	North Carolina State University
Ray Goddard	Geneticist	University of Florida
Peter P. Laird (ex officio)	Pathologist	Southeastern Area, State and Private Forestry
W. R. Phelps (ex officio)	Pathologist	Southeastern Area, State and Private Forestry
Harry Powers	Pathologist	Southeastern Forest Experiment Station
Glenn Snow	Pathologist	Southern Forest Experiment Station
Tom Swofford	Forester	Regional Office, USFS
J. P. van Buijtenen	Geneticist	Texas Forest Service
Bruce Zobel	Geneticist	North Carolina State University

Three additional members were added in August of 1972. They are as follows:

Roger Blair	Geneticist	International Paper Company
Ronald Dinus	Geneticist	Southern Forest Experiment Station
Robert Schmidt	Pathologist	University of Florida

We are indebted to these committee members and other workers who submitted suggestions or assistance in the evaluation (see Table I, Appendix) for the success of the testing center. These contributions have saved the program two to three years of developmental pains. The program is also indebted to W. R. Phelps and Donald P. Graham for their administrative assistance and program backing in the Atlanta and Washington Offices of Forest Pest Management and Forest Pest Control, respectively.

General Design

Seed from 36 families of pine (15 slash and 21 loblolly) were supplied for testing by various agencies and companies involved in tree improvement. The families were chosen to represent a range in susceptibility based on their previous performance in field and/or laboratory tests. Throughout the report seed lots are referred to only by arbitrarily assigned numbers. Companies and agencies contributing seed are listed in Table II of the Appendix.

The basic unit used in the test was 20 seedlings equally spaced in a 13 1/2" x 5" x 4 1/4" plastic planter tray. Five separate test runs (A, B, C, D, E) each a month apart, were established in order to test the reliability of the method over a period of time. In each test run every seed lot was to be represented by five replicate trays of 20 seedlings each. Significance of the variance between seed lots, run dates, and replicate trays was

analyzed by standard analysis of variance methods. In the final analysis several seed lots had to be eliminated due to lack of sufficient replication. Loss of replicates was due to either poor germination or seed-borne root disease.

The design also included a grouping of the seed lots into triplicate combinations (Table 1, page 18 and Table 7, page Each combination contained at least one susceptible member and one resistant or intermediate member. At the time of the grouping it was realized that some of the previous performance information was at best scanty, while on others it was excellent. We did not expect our laboratory tests to correlate with past performance data in every case. We did expect, however, that our results be the same over the five runs.

Also included in the criteria for grouping was inoculum source. Seed lots were grouped by geographical source and inoculated with inoculum from that same general area.

Procedures and Equipment

A detailed description of the procedures may refer to literature citings or may request a copy of a detailed description of the procedures used by testing personnel (Laird, Knighten, Wolfe, 1973). A brief summary presentation of the complex procedures and equipment is presented here under the following headings:

Aeciospore collection and handling
Culture of oaks
Oak inoculation
Telia and basidiospore harvest
Pine inoculation
Culture of pine
Evaluation of pines for rust

Aeciospore Collection and Handling

Aeciospores were collected in the field during the spring of 1972. Three inoculum sources--southern Alabama, southeastern Georgia, and a northeastern Florida source were used for slash pine. For loblolly, a coastal South Carolina and coastal Georgia mix and a Louisiana source were used. Inoculum collections from each area consisted of a minimum of 10 galls. This insured a good representation of fungal sources from the area sampled.

The spores were collected from the galls using cyclone spore collector (Physics Shop, Iowa State University, Ames, Iowa, Fig. 1) or by tapping the galls with a mallet after wrapping them with wax or notebook paper. Collected spores were placed immediately in ice chests. Insects were

removed within 12 hours by passing the spores through a set of sieve screens. The spores were kept in ice chests or refrigerators until they were prepared for long term storage by desiccation. The spores were first dried for seven days over $CaCl_2$ in vacuum desiccators. Then, using a 72 port Virtis manifold from a freeze dry apparatus, we developed a vacuum desiccation system (Fig. 2) where the spores were further dried and vacuum packed in glass ampoules. Roncadori and Matthews (1966) showed aeciospores can be preserved for several years with little or no loss in viability with vacuum storage techniques.

Culture of Oaks

Northern red oak (*Quercus rubra* L.) acorns were collected in the fall of 1971 and stored at cold temperatures of 1° to 2°C. When needed, the acorns were placed on vermiculite germination beds under a timed water spray system. Germinated acorns with 1- to 3-inch hypocotyls were transplanted into 5-inch diameter pots and grown in a relatively well shaded section of the greenhouse.

Oak Inoculation

Using methods modified from Nighswander and Patton (1965), Snow and Roncadori (1965), and Matthews and Rowan (1972), the oaks were inoculated with a water suspension of aeciospores. The suspension was prepared from aeciospores stored in ampoules under vacuum. The spores were first re-hydrated, then placed in suspension and sprayed in a fine mist on the under surface of young tender oak leaves (14-20 days old).

The inoculated oaks were then incubated for 24 hours in an incubation chamber with a relative humidity of above 96 percent and temperature of 69° to 71°F.

Telia and Basidiospore Harvest

Telial-bearing oak leaves were harvested two weeks after the telia first appeared. According to Powers and Roncarodi (1966), maximum basidiospore harvest is attained at this age. Basidiospores were harvested following procedures similar to that of Matthews et al (1971) by placing the detached leaves stapled to filter paper on the inner surface lid of humidity chambers (Fig. 3) and incubating for 48 hours at 20°C so that as the spores are released from the telial columns they fall into acidified water (pH2) at the bottom of the chamber. The low pH inhibits spore germination and permits the spores to be harvested at the end of a 48-hour period instead of every few hours. A millipore filter system was employed to collect the basidiospores from the acidified water on filter discs (Miller, 1970) (Fig. 4). Several risings were used to remove the acid from the spores before using or storing.

Figure 1. Collection of aeciospores from galls in early spring using cyclone spore collector.

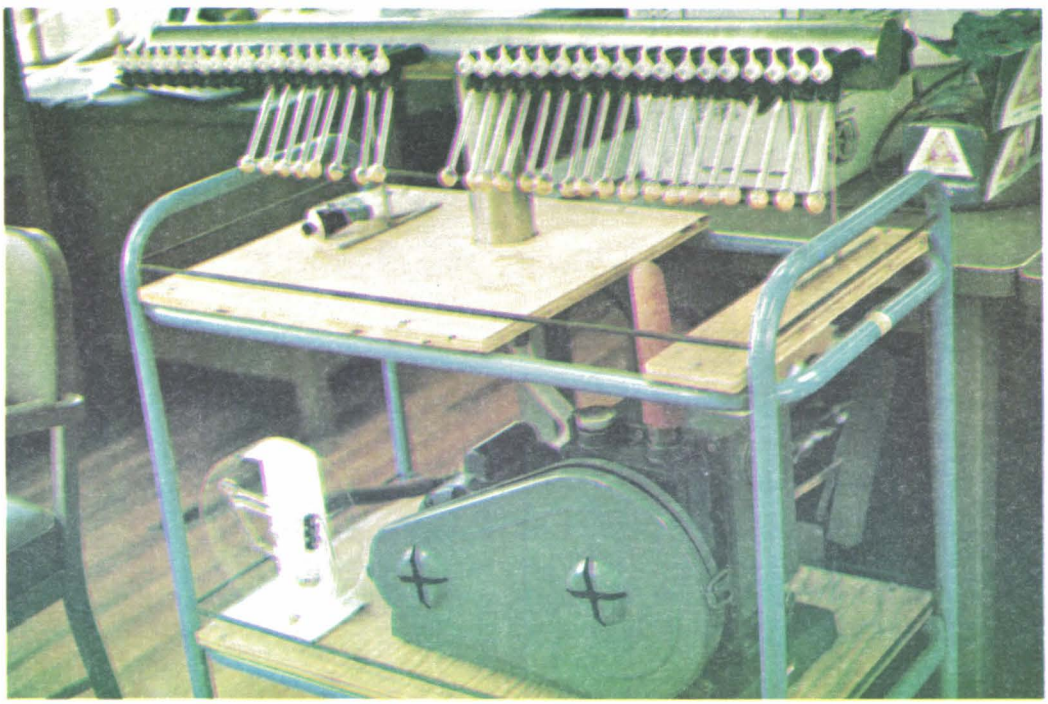

Figure 2. Seventy-two port Virtis vacuum drying manifold used to vacuum pack aeciospores in glass ampules for long term storage.

Figure 3. Leaves bearing telial columns of basidiospores attached to lid of humidity chamber containing acidified water solution collecting medium.

Figure 4. Millipore filtration apparatus used to collect the (orange) aeciospores on filter pad.

Pine Inoculation

Discs of basidiospores may be stored for several weeks, however, in our case spores less than a week old were used in all of the pine inoculations. A water suspension of basidiospores is prepared by washing the spores from the discs into a beaker of water. The inoculum density of the spore solution was determined using modified methods of those developed by Dwinell (Matthews et al, 1971), employing a Coulter Electronic Particle Counter. Inoculum density rates were 75,000 spores/ml for slash and 150,000 spores/ml for loblolly as suggested by the Southeastern Forest Experiment Station.

All of the seedlings were inoculated at approximately six weeks of age with the exception of seed lots 28 through 42 of the D loblolly run of the South Carolina and Georgia coastal inoculum mix. They were inoculated at approximately eight weeks of age because of poor infection on a group of oaks that were being used to culture inoculum. This prevented the collection of sufficient basidiospores to allow inoculation at the designated time.

Trays were sprayed three at a time in the triplicate combination group (Fig. 5). In cases where missing trays occurred, dummy trays were inserted for the spraying procedure. The 3-tray set was sprayed for 30 seconds using a Brinkman Chromatographic sprayer.

The technician applying the spray followed a predetermined patterned spray plan that insured all the seedlings received approximately an equal amount of the spray suspension. This spray plan was thoroughly practiced and pretested before initiating the actual tests. The same technician sprayed all of the replicates throughout the test.

The inoculations were timed by a second technician using a stop watch. Immediately after the completion of the spraying the seedling trays were placed in an incubation chamber for 24 hours where relative humidity was maintained at above 96 percent and temperature at 69° to 71°F.

A schematic diagram of the chamber is presented in Figure 6. The box itself is merely a grocery store type walk-in refrigerated cooler minus the refrigeration system. Inside the box is a sheet metal cone roof with a perforated pipe (D) around its exterior perimeter. This roof is held up by redwood posts. Shelving is attached to the posts. Burlap curtain (C) hangs down from the sheet metal roof's perimeter and is affixed so that water dripping from the perforated pipe keeps the curtain constantly saturated. Water dripping from the curtain falls to chamber floor and collects to form a 2- to 4-inch deep pool over the entire floor surface. A pallet floor extends over the pool. The floor not only offers a relatively firm surface for footing while placing seedling trays on the shelves, but also space to place further trays once the shelves are filled. Constant evaporation from the burlap and water pool on the floor is the main means of keeping the chamber near saturated humidity. A humidifier, controlled by an electric timer set at 3 minutes on 3 minutes off cycle, further

Figure 5. Preparing to spray pine seedling trays with Brinkman chromatographic spray gun.

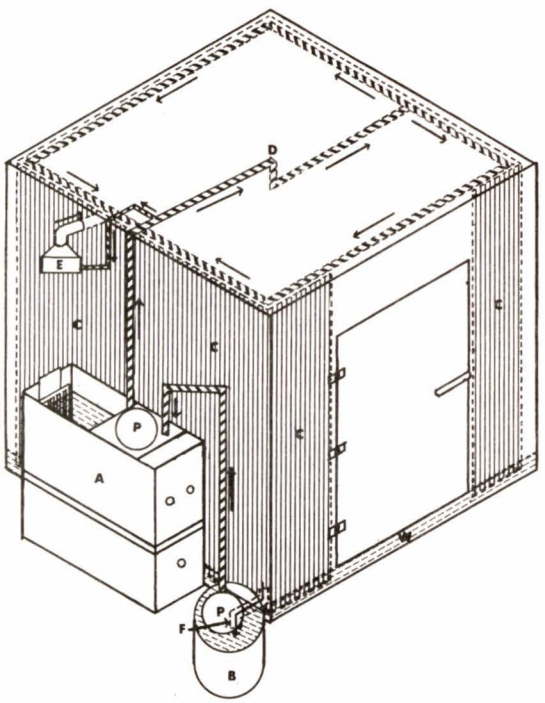

Figure 6. A schematic diagram of post inoculation incubation chamber (see text page 11 for explanation of symbols)

supplements the amount of moist air. The humidifier is attached to the same water system (D) as is the water dripping down the curtain to the chamber floor. The temperature of the water flowing through the whole system is maintained by a Blue M Magni Whirl water bath (Model #MR-3240C-1, Blue M Electric Company, Blue Island, Illinois), which maintains the water at 69°F. plus or minus one degree (A). Two water pumps are used to circulate the water, one from a sump (B) to the water bath and the other from water bath into the pipe circulation system (D). The efficiency of this box has been checked and monitored repeatedly using a Psychon psychrometer and several types of thermometers and weather recorders.

Pine Culture

One of the most important facets of the standardization of this evaluation is that of the pine culture. In our opinion, lack of standardization in pine culture has been one of the major problems in previous resistance testing.

The pines were grown throughout the evaluation in a glass-enclosed greenhouse (Figs. 7 and 8). Temperatures rarely exceeded 90°F. and then only for a brief period of one to two hours. Night temperatures rarely dropped below 40°F. and were normally above 50°F. A standardized day (16 hours) was accomplished by supplementing natural light with wide spectrum very high output Sylvania Gro-Lux florescent lamps.

The soil was analyzed by North Carolina State University soil scientist Dr. Charles Davey. Based on his findings, the seedling trays were fertilized to bring the soil up to standards for good growth. The actual soil mix, soil analysis, and fertilization procedure are listed in the Appendix (Table III). The soil was sterlized using a Famco Electric Sterilizer.

Each seedling was insured an approximately equal growing space with a planting dowel containing 20 evenly spaced pegs to establish seedling location in the tray's soil before insertion of the seedlings (Fig. 9). The pine seed was germinated in vermiculite beds under a mist-a-matic or timed spray system. The seedlings were transplanted to the planting trays as soon as they germinated and before they shed their seed coats.

Evaluation

Evaluation of the seedlings consisted of checking the seedlings for galls at 3, 6, and 9 months. Only trees exhibiting definite stem swellings were counted as successfully infected (Fig. 10).

At the initiation of the study, gall length measurements were also made. This was very tedious work and was found to offer no different information on relative susceptibility or resistance than gall counts. Gall measurements were made only for Runs A and B.

Figure 7. Pines, 2- to 3-months old, growing in greenhouse.

Figure 8. Pines, 6- to 9-months old, growing in greenhouse.

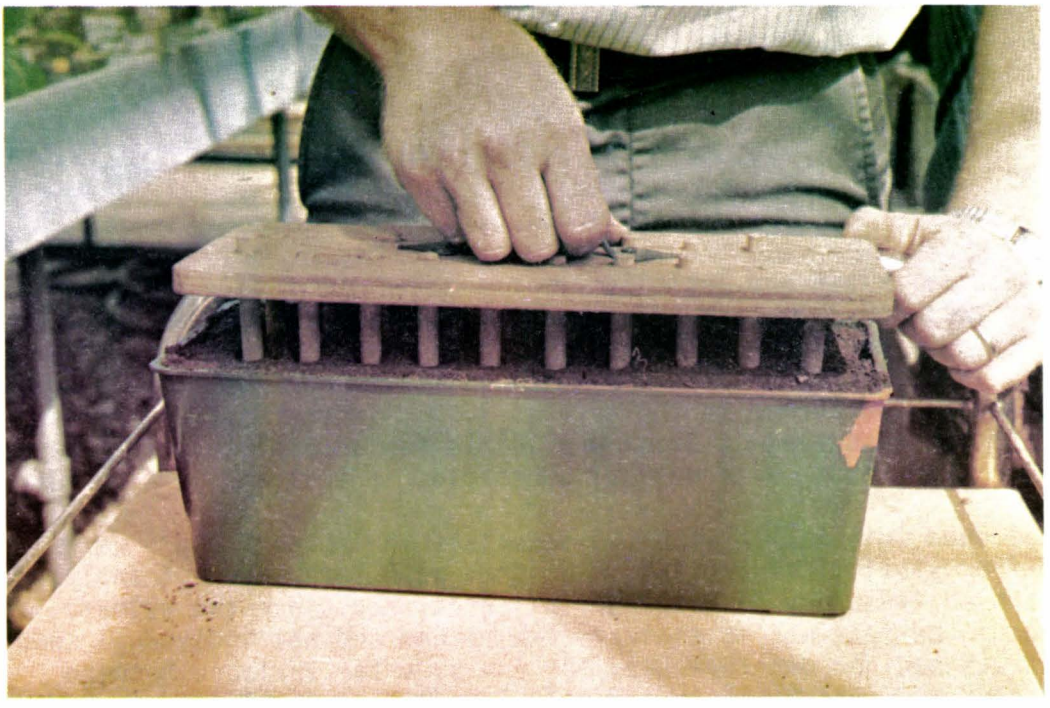

Figure 9. Planting dowel used to regulate pine seedling spacing in planter trays.

Figure 10. Galled susceptible slash pine seedlings.

RESULTS AND DISCUSSION

The results for slash and loblolly are presented separately in the two following sections. In each section the basic results are presented in Table 1 (slash) and Table 7 (loblolly). These tables are condensed forms of Tables IV and V in the Appendix which lists the data by trays. Analyses of variance was performed on the data as listed in the Appendix tables using a method described in Steel and Torrie for a completely randomized design for experiments with unequal subsamples (Steel and Torrie, 1960).

Note that seed lots marked with two asterisks in Tables 1 and 7 were omitted from statistical analysis. Omitted seed lots were not analyzed due to a high frequency of missing replicates, and since the primary function of the test was to evaluate the method and not individual seed lots, it was decided not to weaken the analysis for variance between replications and runs by including seed lots with incomplete data. However, since the number of replications is often adequate for comparisons between seed lots, we have included the data for seed lots with missing replicates in many of the tables with their appropriate asterisks.

Slash Results

The percentage of slash seedlings galled at 3, 6, and 9 months is presented by run in Table 1. Table IV in Appendix presents the data separated further by replicates. Analyses of variance for 3-, 6-, and 9-month readings are listed in Tables 2, 3, and 4 respectively. Seed lot differences are significant at all three readings and are responsible for most of the variance. Differences among runs were significant at 3 months, but by the 6- and 9-month readings these differences had disappeared. Percentage of seedlings galled by run is presented in Table 5. Interestingly enough, gall formation by seed lots at 3 months was not correlated with seedling height growth (Table 5). Duncan's new multiple-range test (Steel and Torrie, 1960) was used to test for significance among seed lot means. This analysis is presented in Table 6.

Slash Discussion

The success of the method as a reliable, repeatable method for testing for resistance in slash is supported by the date in Tables 1 and 6. Table 6 reveals three distinct groups of resistance at all three ages of evaluation. Seed lots 1 and 16 showing good relative resistance, and seed lots 3, 6, and 18 (all three from a mixed to commercial lot of Louisiana slash) showing resistance superior to the remainder of seed lots. Seed lot 4 (Table 1),

although not statistically analyzed, may be placed in the resistant groups Its performance in runs B through E is second only to that of seed lot 1 (Table 1). All other seed lots not analyzed statistically have high rates of infection and may be considered in the susceptible group. Analyses of variance (Tables 2, 3, and 4) demonstrate the nonsignificance of the variance among runs within the seed lots (reliability of the test) at 3-, 6-, and 9-month readings. Differences were not even significant between runs at the 6- and 9-month readings. Although differences at 3 months between the runs were statistically significant, practically speaking these differences (Table 5) are so small (maximum of 7 percent compared to differences between susceptibility and resistance 30 to 40 percent) that they are of no consequence in the ability to distinguish for resistance. It is hypothesized these small differences may be due to seasonal differences effect on day length and greenhouse temperatures in relation to gall development. Both 3- and 6-month evaluations appear to give good estimates of 9-month results. In fact, 6-month and 9-month results are practically identical. For the present testing, we plan to hold all slash pine seed lots for 6 months to insure maximum symptom (gall) expression. Eventually the holding period may be decreased to 3 months, especially for highly susceptible lots.

The reader may be somewhat disappointed in the correlation of our tests with previous field performances as listed in Table 1. Seed lots 1 and 16 were found to be definitely more resistant then the others as expected; but the rest were all more susceptible than the lots (3, 6, and 18) derived from a commercial lot of seed from Louisiana. The following is offered as a brief explanation of why seed lots 4, 7, 8, 10, and 13 did not show more resistance in our tests.

First of all seed lot 4 did show considerable resistance, but was not analyzed statistically due to a lack of sufficient replicates. Previous results for 7 and 8 were based only on one previous test and have not been substantiated in this test or later observations by the University of Florida. Seed lots 10 and 13 should have exhibited at least some relative resistance and we are somewhat disappointed they did not. We feel this may be due to a high rate of inoculum density used (75,000 spores/ml.) and that families such as these can be distinguished from more susceptible families by lowering the inoculum density. We have initiated studies using lower inoculum densities and the results are extremely encouraging.

Loblolly Results

The percentage of loblolly seedlings galled at 3, 6, and 9 months is presented by run in Table 7. Table V in the Appendix presents the data separated further by replicates.

Analyses of variances for 3-, 6-, and 9-month data for loblolly pine is listed in Tables 8, 9, and 10, respectively.

TABLE I SLASH PINE RESULTS BY PERCENT GALLED AT THREE, SIX, AND NINE MONTH READINGS

Seed Lot	Inoculum Source Co. & State	Resistance *** Information	Percent Galled (5 trays of 20 seedlings each) Runs A-E 3 Month Reading A	B	C	D	E	X	Runs A-E 6 Month Reading A	B	C	D	E	X	Runs A-E 9 Month Reading A	B	C	D	E	X
1	Nassau, Fla.	.77 (12)	52	62	65	54	66	60	56	64	60	51	63	59	54	69	71	54	66	63
2	Nassau, Fla.	-.93 (4)	92	95	96	93	93	94	95	95	95	93	96	95	97	95	98	95	96	96
3*	Nassau, Fla.	None	81	87	90	71	82	82	88	88	87	81	90	87	90	86	87	80	88	86
4**	Nassau, Fla.	.20 (5)	X	49	75	66	68	64	X	60	71	64	65	65	X	57	71	64	65	68
5	Nassau, Fla.	-.60 (7)	92	92	98	95	96	95	97	97	98	96	96	97	95	98	97	96	96	96
6*	Nassau, Fla.	None	76	85	94	86	77	83	89	93	81	95	84	88	87	92	85	94	89	89
7	Dixie, Fla.	1.45 (1)	94	96	99	91	93	95	96	97	98	99	98	98	97	99	99	96	98	98
8	Dixie, Fla.	.94 (1)	93	99	96	95	91	96	97	97	95	94	95	96	97	97	96	93	95	96
9	Dixie, Fla.	-.18 (4)	84	96	98	89	80	89	97	95	96	96	88	94	96	98	98	94	90	95
10	Appling, Ga.	.43 (10)	93	91	94	86	83	89	97	96	99	98	95	97	98	98	98	99	99	98
11	Appling, Ga.	(-.16) (10)	96	99	96	95	95	96	99	96	98	100	96	98	99	97	98	100	98	98
12	Appling, Ga.	(-1.13) (2)	97	99	100	94	96	97	98	100	100	100	100	100	99	100	100	99	99	99
13**	Appling, Ga.	.42 (4)	X	X	89	82	85	85	X	X	100	100	100	100	X	X	94	98	100	97
14	Appling, Ga.	-.65 (9)	96	96	97	91	93	95	96	98	99	99	97	98	96	97	97	97	98	97
15	Appling, Ga.	-1.60 (1)	94	96	95	93	87	93	96	98	97	99	95	97	97	98	96	99	96	97
16	Washington, Ala.	.78 (6)	75	66	62	65	56	65	80	75	78	84	71	78	82	75	75	89	77	80
17	Washington, Ala.	(-.73) (7)	95	93	96	91	86	92	100	100	97	93	95	97	100	100	97	94	96	97
18*	Washington, Ala.	None	75	86	80	69	69	76	84	89	89	86	90	88	88	91	84	83	91	87

* Mixed commercial seed lot from Louisiana that was used as a filler.

** Lots not included in statistical analysis due to poor germination percent or root rot.

*** Resistance information is based on previous tests by the University of Florida. Positive values are most resistant, negative most susceptible. Numbers in parenthesis indicate number of tests.

X Missing data.

TABLE 2 ANALYSIS OF VARIANCE OF SLASH PINE DATA FOR THREE MONTH READING (TABLE IV APPENDIX)

Source of Variation	df	SS	M.S.	F
Among runs	(80-1) 79	55,071.10		
Seed lots	(16-1) 15	47,421.32	3,161.42	43.76**
Runs (A-E)	(5-1) 4	3,315.71	828.92	11.47**
Among runs within seed lots (experimental error) (16-1) (5-1)	60	4,334.07	72.23	1.35
Among replicate trays within runs (sampling error)	302	16,193.40	53.62	
Total	(382-1)381	71,264.5		

** Significant at the 1 percent level.

TABLE 3 ANALYSIS OF VARIANCE OF SLASH PINE DATA FOR SIX MONTH READING (TABLE IV APPENDIX)

Source of Variation	df	SS	M.S.	F
Among runs	79	42,464.06		
Seed lots	15	39,782.31	2,652.15	63.92**
Runs (A-E)	4	192.25	48.06	1.16
Among runs within seed lots (experimental error)	60	2,489.50	41.49	1.05
Among replicate trays within runs (sampling error)	302	11,961.4		
Total	381	54,425.49		

** Significant at the 1 percent level.

TABLE 4 ANALYSIS OF VARIANCE OF SLASH PINE DATA FOR NINE MONTH READING (TABLE IV APPENDIX)

Source of Variation	df	SS	M.S.	F
Among runs	79	36,674.84		
Seed lots	15	33,333.23	2,222.21	42.92**
Runs (A-E)	4	208.58	52.14	1.01
Among runs within seed lots (experimental error)	60	3,106.03	51.77	1.32
Among replicate trays within runs (sampling error)	302	11,802.57	39.08	
Total	381	48,450.41		

** Significant at 1 percent level.

TABLE 5 PERCENTAGE OF SLASH PINE SEEDLINGS GALLED BY RUN.

Run	Month of Inoculation	Mean Seedling Height 3 Months	Mean Percentage Galled 3-Month Reading	6-Month Reading	9-Month Reading
A	March	9.6	86	91	92
B	April	9.0	90*	93	93
C	May	11.4	91*	92	92
D	June	9.8	85	92	91
E	July	11.3	84	91	92

* Significantly different at 5 percent level, Duncan's new multiple-range test (Steel and Torrie, 1960).

TABLE 6 COMPARISON BETWEEN SEED LOT MEANS FOR SLASH PINE 3, 6, AND 9 MONTH READINGS

3 Months

Seed lot	1	16	18	3	6	10	9	17	15	2	7	14	5	8	11	12
Percent galled	60	64	76	82	83	89	89	92	93	94	95	95	95	95	96	97

6 Months

Seed lot	1	16	3	18	6	9	2	17	8	10	5	15	7	14	11	12
Percent galled	59	78	87	88	88	94	94	96	96	97	97	97	98	98	98	99

9 Months

Seed lot	1	16	3	18	6	9	2	8	5	17	15	14	10	7	11	12
Percent galled	63	80	86	87	89	95	96	96	96	97	97	97	98	98	98	99

Seed lots not underlined by same line are significantly different at 5% level according to Duncans new multiple range test (steel and Torrie, 1960).

As in slash pine, most of the variance is due to the differences among seed lots. Run differences are more apparent in loblolly than they were in slash, and became significant in the 6- and 9-month reading. Data grouped by run is presented in Table 11, Duncan's new multiple range test (Steel and Torrie, 1960) was used to test for significance between seed lot means (Table 12).

Loblolly Discussion

Although the method again proves to be a promising method of evaluating for resistance, the loblolly seed lots are not as distinctly separated into resistant and susceptible groups as those of slash. Among runs within the seed lot variance, although significant, is not large enough to affect the large differences between seed lots. Table VI in the Appendix summarizes the standard deviations between runs and between replicates. The standard deviations are always higher (sometimes nearly twice) in loblolly than in slash.

Also of interest in Table VI is that the standard deviations between replicates is usually higher than the standard deviations between the runs of a seed lot, as indicated by the higher values for the mean of the standard deviations between replicates of the five runs than for the standard deviation among the run means. This indicates the natural variation in seed lots is responsible for a greater portion of the variance than the testing method. At least in the submitted seed lots there appears to be a more gradual range in the variation of resistance in loblolly than in slash. Comparing the results in Table 6 for slash with those of Table 12 for loblolly emphasizes the differences. Slash breaks into three definite groups while loblolly exhibits a wide range of differences in resistance.

In loblolly, as opposed to slash, a difference between the results of the runs was significant at the 6-and 9-month readings (Tables 8, 9, and 10). When the data were grouped by run (Table 11) it was obvious that the D run was significantly lower than the others. This was easily traced back to the seed lots 18 through 42 of run D which were inoculated at 8 weeks instead of 6. The reader can refer to the D columns of the 6- and 9-month reading for seed lots 18 through 42 in Table 7 and readily see the lower infection levels in run D.

The lower infection in the D run is not totally unexpected as one would expect a decrease in susceptibility as the seedlings mature and the tissue begins to harden. This is a good case point for the need for careful standardization and controlled testing procedures, especially if results between different tests are to be compared.

Loblolly also exhibits some change between seed lot rankings between the 3-, 6-, and 9-month readings. The change in rankings (Table 12) is within seed lots exhibiting either resistance or susceptibility, not between resistant and susceptible groups. Seed lot 33 rating, for example, shows more galls at the 3-month rating (4th rank, 72 percent infected) than at the 9-month (1st rank, 58 percent infected) ratings. Also note that seed

TABLE 7 LOBLOLLY PINE RESULTS BY PERCENT INFECTION AT THREE, SIX, AND NINE MONTH READINGS

Seed Lot	Inoculum Source	Resistance*** Information	Runs A-E 3 Month Reading A	B	C	D	E	X̄	Runs A-E 6 Month Reading A	B	C	D	E	X̄	Runs A-E 9 Month Reading A	B	C	D	E	X̄
19**	Natchitoches, La.	.53	79	64	71	80	72	73	80	67	86	82	73	78	83	72	81	78	72	77
20**	Natchitoches, La.	.77	76	80	76	90	X	81	95	85	97	99	X	94	97	95	95	99	X	97
21*	Natchitoches, La.	None	79	83	74	86	69	78	79	86	79	91	78	83	84	90	76	91	78	84
22	Natchitoches, La.	.30	83	63	80	87	72	77	86	86	89	90	86	87	91	91	89	94	84	90
23	Natchitoches, La.	.58	91	71	87	91	85	85	93	88	93	94	93	92	93	90	91	93	95	92
24*	Natchitoches, La.	None	81	84	81	81	81	82	90	87	85	89	89	88	88	90	84	92	87	88
25	Natchitoches, La.	.44	75	86	81	74	84	80	84	91	93	88	95	90	88	91	93	89	95	91
26	Natchitoches, La.	.56	83	84	79	75	90	83	88	89	92	80	96	89	87	92	90	81	94	89
27	Natchitoches, La.	.80	75	78	81	91	86	82	90	90	96	95	95	93	91	97	95	95	95	95
28	Coastal S.C. & Ga.	R(1)	81	93	81	86	81	84	95	97	97	88	88	93	94	96	96	89	90	93
29**	Coastal S.C. & Ga.	I(2)	80	60	71	75	80	73	78	65	90	59	72	73	66	53	67	54	56	59
30	Coastal S.C. & Ga.	S(2)	96	81	80	92	94	89	98	94	95	90	96	95	98	95	95	93	97	96
31	Coastal S.C. & Ga.	R(1)	85	66	60	66	88	73	92	86	86	73	95	86	93	86	84	72	95	86
32**	Coastal S.C. & Ga.	I(2)	70	65	68	60	71	67	73	78	76	55	84	73	78	78	80	57	81	75
33	Coastal S.C. & Ga.	I(2)	75	61	67	71	84	72	72	61	62	53	78	65	69	52	59	47	63	58
34	Coastal S.C. & Ga.	R(1)	91	86	85	80	86	86	94	90	92	82	91	89	95	91	93	81	92	90
35	Coastal S.C. & Ga.	I(2)	64	60	69	65	59	63	70	75	80	65	62	70	73	73	78	68	62	70
36	Coastal S.C. & Ga.	S(2)	92	96	89	79	88	89	96	96	94	84	82	90	96	96	94	82	96	93
37	Coastal S.C. & Ga.	R(3)	55	47	61	47	55	53	66	63	83	49	63	65	68	55	73	46	63	61
38	Coastal S.C. & Ga.	I(3)	96	87	86	89	91	90	97	98	98	86	94	95	98	97	93	88	94	94
39**	Coastal S.C. & Ga.	S(3)	88	-	88	77	93	87	99	-	98	88	99	95	94	-	98	89	99	95
40	Coastal S.C. & Ga.	R(3)	67	66	68	57	69	66	83	79	78	61	77	76	87	79	77	68	82	79
41	Coastal S.C. & Ga.	I(3)	83	86	71	79	80	80	90	90	82	81	87	86	90	92	83	83	88	87
42*	Coastal S.C. & Ga.	None	82	76	86	87	90	84	91	86	95	88	92	90	90	87	95	88	93	91

* Mixed wild seed lot from North Carolina used as a filler.

** Lots not included in statistical analysis due to poor germination percent or root rot.

*** Resistance information based on various methods. 1/ U. S. Forest Service screening at Gulfport, Mississippi using inoculation sheds. Data expressed in percent galled. 2/ Resistance merely expressed qualitatively, R=resistant, I=intermediate, S=susceptible. Numbers in parenthesis indicate different contributors (companies).

TABLE 8 ANALYSIS OF VARIANCE OF LOBLOLLY PINE DATA FOR THREE MONTH READING (TABLE 5 APPENDIX)

Source of Variation	df	SS	M.S.	F
Among runs	(95-1) 94	55,764.83		
Seed lots	(19-1) 18	27,346.38	1,519.24	4.02**
Run (A-E)	(5-1) 4	1,236.08	309.02	0.82
Among runs within seed lots (experimental error)	72	27,183.37	377.53	2.55**
Among replicate trays within runs (sampling error)	360	53,175.17	147.70	
Total	(455-1)454	108,940.43		

** Significantly different 1 percent level.

TABLE 9 ANALYSIS OF VARIANCE OF LOBLOLLY PINE DATA FOR SIX MONTH READING (TABLE 5 APPENDIX)

Source of Variation	df	SS	M.S.	F
Among runs	94	51,755.03		
Seed lots	18	38,701.11	2,150.66	15.31**
Runs	4	2,940.85	737.01	5.24**
Among runs within seed lots (experimental error)	72	10,113.07	140.46	1.80**
Among replicate trays within runs (sampling error)		28,809.73	77.93	
Total	454	79,809.73		

** Significantly different 1 percent level.

TABLE 10 ANALYSIS OF VARIANCE OF LOBLOLLY PINE DATA FOR NINE MONTH READING (TABLE 5 APPENDIX)

Source of Variation	df	SS	M.S.	F
Among runs	94	63,839.71		
Seed lots	18	52,521.31	2,917.85	24.09**
Runs	4	2,597.53	649.38	5.36**
Among runs within seed lots (experimental error)	72	8,720.87	121.12	1.81**
Among replicate trays within runs (sampling error)	360	24,047.75	66.80	
Total	454			

**Significantly different 1 percent level.

TABLE 11 PERCENTAGE OF LOBLOLLY PINE SEEDLINGS GALLED BY RUN

Run	Month of Inoculation	Mean Percentage Galled 3 Months Reading	6 Months Reading	9 Months Reading
A	March	81	87	88
B	April	77	86	87
C	May	77	87	86
D	June	78	80*	81*
E	July	80	86	86

*Significantly different 5 percent level, Duncan's new multiple range test (Steel and Torrie, 1960)

TABLE 12 COMPARISONS BETWEEN SEED LOT MEANS
FOR LOBLOLLY PINE 3, 6, AND 9 MONTH READINGS

3 Month

Seed lot	37	35	40	33	31	22	21	41	25	29	27	26	42	28	23	34	36	30	38
Percent galled	53	63	66	72	73	77	78	80	80	82	82	83	84	84	85	86	89	89	90

6 Month

Seed lot	37	33	35	40	21	31	41	22	24	26	34	25	36	42	23	28	27	30	38
Percent galled	65	65	70	76	83	86	86	87	88	89	89	90	90	90	92	93	93	95	95

TABLE 12 (Cont'd)

	9 Months																	
Seed lot	33	37	35	40	21	31	41	24	26	22	34	25	42	23	36	28	38	27	30
Percent galled	58	61	70	79	84	86	87	88	89	90	90	91	91	92	93	93	94	95	96

Seed lots not underlined by the same line are significantly different at the 5% level according to Duncans new multiple range test (Steel and Torrie, 1960).

lot 29, although it is not included in statistical analysis, is also decreasing (73-59 percent).

The decrease here resulted largely from a healing over of galls that were evidenced earlier. At any rate for loblolly readings it is presently recommended that 6-month reading periods are mandatory for all seed lots and up to 9-month readings should be done for those exhibiting some resistance.

In general, reasons for inconsistencies of our data with previous test data in loblolly cannot be attributed to any one cause. Previous test data came from many different sources and consequently was obtained in many different ways.

Seed lots 37 and 40 both have extensive confirmed backgrounds of resistance. Both proved resistant here. Seed lots 32, 33, and 35 all came from one company who rated them as having some resistance as compared to their susceptible family (30 and 36). Our results not only bear out this observation but also indicate that 32, 33, and 35 may have as good or better resistance than some of the other seed lots considered as our best selections (37 and 40).

Susceptible seed lots in coastal South Carolina and Georgia were confirmed as susceptible here.

We certainly expected some of the lots, 28 and 38 for example, to at least show some intermediate resistance. However, as in slash we expect more intermediate resistance to begin to appear as we lower inoculum density. Results of current studies with lower inoculum densities are most encouraging.

General Discussion

The results of this initial evaluation are gratifying not only to the authors but to all concerned. However, as previously mentioned, during the course of the evaluation it became readily apparent that, while the results were excellent in that highly susceptible lots were being distinguished from those having varying degrees of resistance, it was highly possible that some lots exhibiting relative resistant traits in previous tests were turning up susceptible here. Since infection rates in susceptible lines were almost total (90 percent + galled) and greater than 50 percent in resistant lots, it was reasoned that perhaps, if inoculum density could be lowered, a more desirable range of infection might be obtained. For example, 10 to 20 percent infected for resistant, 20 to 60 percent for intermediate, and greater than 60 percent infected for susceptible. It is possible that some lots showing susceptibility in our test would be intermediate in tests using lowered inoculum densities.

An evaluation of lower inoculum densities using a completely automated mechanically standardized inoculation spray rig is currently underway and nearly complete. Results of this evaluation are extremely encouraging and will be forthcoming shortly.

Operational testing for resistance is already underway on a limited basis, and by 1975 it is hoped a full scale operational program will be well underway.

Conclusions

1. The basic water suspension spray technique has definite merit as a means of differentiating highly susceptible seed lots from those showing varying degrees of resistance for both loblolly and slash pine.

2. This inoculation technique is currently being refined and improved. Improvements in the development of automated spray systems and adjustments of inoculum densities are yielding extremely encouraging preliminary results. We are further cooperating with the Southeastern and Southern Forest Experiment Stations in a Research and Development Program to further improve the reliability, sensitivity, and logistics of the program.

3. Operational testing for slash and loblolly pine resistance is currently underway on a limited scale basis (600 seed lots per year), and the facilities will eventually be expanded to handle up to 2,500 seed lots per year.

BIBLIOGRAPHY

Balthis, R. F. and D. A. Anderson. 1944. Effect of cultivation in a young slash pine plantation on the development of Cronartium cankers and forked trees. J. Forest. 42: 926-927.

Barber, J. C. 1964. Inherent variation among slash pine progenies at the Ida Cason Callaway Foundation. U.S.D.A. Forest Serv. Southeast. Forest Exp. Sta. Res. Pap SE-10, Asheville, N. C., 90 p.

Blair, R. L. 1970. Quantitative inheritance of resistance to fusiform rust in loblolly pine. Ph.D Thesis, North Carolina State Univ., Raleigh, N.C.

Boggess, W. R. and R. Stahelin. 1948. The incidence of fusiform rust in slash pine plantations receiving cultural treatments. J. Forest. 46: 683-685.

Borlaug, N. E. 1964. Basic concepts which influence the choice of methods for use in breeding for disease resistance in cross-pollinated and self-pollinated crop plants. In H. D. Gerhold, E. J. Schreiner, R. E. McDermott, and J. A. Winieski (eds), Breeding Pest Resistant Trees, Pergamon Press, New York: 327-348.

_____ 1972. A cereal breeder and ex-forester's evaluation of the progress and problems involved in breeding rust resistant forest trees: moderators summary in Biology of Rust Resistance in Forest Trees. Proceedings of a NATO-IUFRO Institute, Moscow, Idaho, Aug. 1969.

Dwinell, L. D. 1972. An inoculation system for *Cronartium fusiforme*. In Biology of Rust Resistance in Forest Trees. Proceedings of a NATO-IUFRO Institute, Moscow, Idaho, Aug. 1969. U.S.D.A. Misc. Pub.1221: 327-330.

Goddard, R. E. and J. T. Arnold. 1966. Screening select slash pines for resistance to fusiform rust by artificial inoculation. In H. D. Gerhold, E. J. Schreiner, R. E. McDermott, and J. A. Winieski (eds), Breeding Pest Resistant Trees, Pergamon Press New York: 431-435.

Hodges, C. S. 1962. Diseases in southeastern forest nurseries and their control. U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta. Res. Pap. 142, 16 p.

Jewell, F. F. 1959. Disease resistance studies in tree improvement research. Fifth Southern Conference on Forest Tree Improvement Proceedings, 18-20 p.

_____ 1961. Infection of artificially inoculated shortleaf pine hybrids with fusiform rust. Plant Dis. Rep. 45: 639-640.

_____ and B. W. Henry. 1966. Breeding for resistance to southern fusiform rust. Proc. Ninth International Congress 2: 1694-1695.

_____ and S. L. Mallett. 1964. Resistance to fusiform rust in slash pine as shown by artificial inoculation. Phytopathology 54: 1294.

Kinloch, B. B. and R. W. Stonecypher. 1969. Genetic variation in susceptibility to fusiform rust in seedlings from a wild population Population of loblolly pine. Phytopathology 59: 1246-1255.

Laird, P. P., J. L. Knighten, and R. L. Wolfe. 1973. Laboratory and greenhouse procedure guide used in screening nine families for resistance to fusiform rust. U.S.D.A. Forest Serv., Southeast. Area Forest Pest Mgt., Asheville, N.C.

Lamb, H. 1937. Rust canker diseases of southern pines. U.S.D.A. Forest Serv. Exp. Sta. Occas. Pap 72, 7 p.

Lewis, R. A. and E. B. Cowling. 1970. Proposal for creation of a southern pine rust resistance testing center. Unpublished manuscript, N. C. State Univ., Dept. Plant Pathology.

Matthews, F. R., S. J. Rowan, T. Miller, L. D. Dwinell, and H. J. Duncan. 1971. Procedures used in Fusiform Rust Research. Office Report Southeast. Forest Exp. Sta., Athens, Ga., 16 p.

_____ and S. J. Rowan. 1972. An improved method for large scale inoculations of pine and oak with *Cronartium fusiforme* Plant Dis. Rep. 56: 931-934.

Miller, T. 1970. Inoculation of slash pine seedlings with stored basidiospores of *Cronartium fusiforme*. Phytopathology 60: 1773-1774.

Nighswander, J. E. and R. F. Patton. 1965. The epidermiology of the jack pine-oak gall rust (*Cronartium quercum*) in Wisconsin. Can. J. Bot. 43: 1561-1580.

Patton, R. F. 1972. Inoculation methods and problems in testing eastern white pine for resistance to *Cronartium ribicola*. In Biology of Rust Resistance in Forest Trees. U.S.D.A. Misc. Pub. 1221: 373-385.

_____ 1972. Tree rust inoculation problems and techniques section: moderator's summary. In Biology of Rust Resistant Forest Trees. U.S.D.A. Misc. Pub. 1221: 391-392.

Phelps, W. R., et al. 1972. Alabama fusiform rust survey. U.S.D.A. Forest Serv. Southeast. Area and Alabama Forest. Comm.

Powers, H. R. 1969. Reduction of disease losses in pine plantations. Alabama Forest Products 12: 71-75.

_____ and R. W. Roncadori. 1966. Teliospore germination and sporidial production by *Cronartium fusiforme*. Pl. Disease Rep. 50: 432-434.

Roncadori, R. W., and F. R. Matthews. 1966. Storage and germination of aeciospores of *Cronartium fusiforme*. Phytopathology 56: 1328-1329.

Roth, E. R. and C. W. Chellman. 1971. Florida fusiform rust survey 1971. U.S.D.A. Forest Serv., Southeast. Area and Florida Div. Forest.

_____ and H. W. Echols. 1971. Mississippi fusiform rust survey 1971. U.S.D.A. Forest Serv., Southeast. Area and Mississippi Forest. Comm.

_____ and J. E. Graham. 1971. South Carolina fusiform rust survey 1971. U.S.D.A. Forest Serv., Southeast. Area and South Carolina Comm. Forest.

_____ and W. H. McComb. 1971. Georgia fusiform rust survey 1971. U.S.D.A. Forest Serv., Southeast. Area and Georgia Forest. Comm.

_____ and L. H. Nachod. 1971. Louisiana fusiform rust survey 1971. U.S.D.A. Forest Serv., Southeast. Area and Louisiana Forest. Comm.

_____ and J. V. Tiner. 1971. Arkansas fusiform rust survey 1971. U.S.D.A. Forest Serv., Southeast. Area and Arkansas Forest. Comm.

Schmidt, Robert A. 1972. A literature review of inoculation techniques used in studies of fusiform rust. In Biology of Rust Resistance in Forest Trees. Proceedings of a NATO-IUFRO Institute, Moscow, Idaho, Aug. 1969. U.S.D.A. Forest Serv. Misc. Pub. 1221: 341-356.

Snow, G. A. 1968. Time required for infection of pine by *Cronartium fusiforme* and effect of field and laboratory exposure after inoculation. Phytopathology 58: 1547-1550.

_____ and A. G. Kais. 1972. Technique for inoculating pine seedlings with *Cronartium fusiforme*. Biology of Rust Resistance in Forest Trees. Proceedings of a NATO-IUFRO Institute, Moscow, Idaho, Aug. 1969. U.S.D.A. Forest Serv., Misc. Pub. 1221: 325-326.

_____ and R. W. Roncadori. 1965. Oak leaf age and susceptibility to *Cronartium fusiforme*. Pl. Dis. Rep. 49: 972-975.

Steel, R. G. and J. H. Torrie. 1960. Principles and procedures of statistics. New York: McGraw-Hill Book Co., Inc., 481 p.

U. S. Department of Agriculture. 1958. Timber resources for America's future. Resource Rep. 14: 713 p.

Wells, O. O., and P. C. Wakeley. 1966. Geographic variation in survival, growth, and fusiform rust infection of planted loblolly pine. Forest Sci. Monograph 11: 40 p.

APPENDIX

APPENDIX

TABLE I CONTRIBUTORS (OTHER THAN COMMITTEE MEMBERS) TO THE SUCCESS OF THE FUSIFORM RUST RESISTANCE TESTING PROGRAM

Contributor	Profession	Affiliate
Walter Beers	Forester	Buckeye Cellulose
C. B. Davey	Soil Scientist	North Carolina State University
Horace Duncan	Technician	SE Forest Experimental Station, U.S.F.S.
Dave Dwinell	Pathologist	SE Forest Experimental Station, U.S.F.S.
Al Kais	Pathologist	Southern Forest Experimental Station, U.S.F.S.
Fred Mathews	Pathologist	SE Forest Experimental Station, U.S.F.S.
Gene McGhee	Forester	SE Forest Experimental Station, U.S.F.S.
Tom Miller	Pathologist	SE Forest Experimental Station, U.S.F.S.
Bill Pawuk	Pathologist	Forest Pest Management, U.S.F.S.
James Rowan	Pathologist	SE Forest Experimental Station, U.S.F.S.
O. O. Wells	Geneticist	Southern Forest Experimental Station, U.S.F.S.
Marvin Zoerb	Forester	Union Camp Corporation

TABLE II AGENCIES CONTRIBUTING SEED FOR TESTING

1. Brunswick Corporation
2. Container Corporation
3. Continental Can
4. Hudson Pulp and Paper Company
5. International Paper Company
6. Rayonier Corporation
7. Scott Paper Company
8. St. Regis Paper Company
9. Union Camp Corporation
10. U. S. Forest Service
11. Westvaco

TABLE III SOIL ANALYSIS AND AMENDMENTS

Attribute (original)	Sample 1	Sample 2
pH	5.2	5.2
Total N (%)	0.2	0.2
Organic matter (%)	13.1	12.9
Soluble Salts (ppm)	< 150	< 150
Available Nutrients (ppm)		
Phosphorus	0.72	0.67
Potassium	50	48
Calcium	264	264
Magnesium	48	48
Manganese	16	16
Added (ppm)		
Phosphorus (elemental)**	25	
Nitrogen (elemental)*	50	

---

* in form of NH_4NO_3

** in form of Na_2HPO_4

APPENDIX

TABLE IV SLASH PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #1

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	53	53	53	79	86	86	63	56	69	62	60	60	65	65	71
	53	53	63	41	44	47	67	53	64	40	35	30	74	74	63
	53	63	53	45	50	70	78	72	84	61	61	72	61	53	59
	48	56	50	76	78	74	56	56	69	50	50	45	50	50	69
	53	53	53	68	63	70	61	61	67	55	50	61	79	74	68
$\bar{X}$	52	56	54	62	64	69	65	60	71	54	51	54	66	63	66
σ	22	43	49	17.7	17.9	14.1	8.3	7.5	7.8	9.0	10.5	16.3	11.3	11.3	49

3 month $\bar{X}$ 59.6 σ6.4)
6 month $\bar{X}$ 58.8 σ5.4) - for all 5 runs
9 month $\bar{X}$ 62.8 σ8.2)

Seed Lot #2

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	85	85	90	90	90	90	100	100	100	89	95	95	84	89	89
	95	100	100	95	95	95	90	90	100	95	95	95	95	100	100
	95	100	100	100	100	100	95	95	95	95	95	95	100	100	100
	-	-	-	90	90	90	95	95	100	100	95	95	95	95	95
	-	-	-	100	100	100	100	95	95	85	85	95	90	95	95
$\bar{X}$	92	95	97	95	95	95	96	95	98	93	93	95	90	96	96
σ	5.7	8.6	4.1	5.0	5.0	5.0	4.2	3.5	2.7	5.9	4.5	0.0	6.1	4.6	4.6

3 month $\bar{X}$ 93.8 σ1.6)
6 month $\bar{X}$ 94.7 σ1.1) - for all 5 runs
9 month $\bar{X}$ 96.0 σ1.3)

Seed Lot #3

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	75	80	85	90	90	85	90	80	85	75	75	80	85	90	90
	75	90	90	94	89	89	95	95	90	70	80	75	80	80	80
	89	90	95	90	90	90	85	85	85	80	90	90	70	95	90
	85	100	100	78	84	79	90	90	90	60	85	80	84	100	100
	80	80	80	85	85	85	90	85	85	70	75	75	90	85	80
$\bar{X}$	81	88	90	87	88	86	90	87	87	71	81	80	82	90	88
σ	6.2	8.4	7.9	6.2	2.9	4.4	3.5	5.7	2.7	7.4	6.5	6.1	7.5	7.9	8.3

3 month $\bar{X}$ 82.2 σ7.3)
6 month $\bar{X}$ 86.7 σ3.4) - for all 5 runs
9 month $\bar{X}$ 86.1 σ3.8)

Seed Lot #4

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	-	-	-	55	65	65	65	60	65	65	65	70	75	60	65
	-	-	-	55	60	65	90	70	75	73	68	63	75	65	65
	-	-	-	40	75	65	70	72	72	60	75	75	80	75	75
	-	-	-	50	45	40	-	-	-	65	65	60	60	65	60
	-	-	-	45	55	50	-	-	-	66	73	53	50	55	60
$\bar{X}$	X	X	X	49	60	57	75	67	71	66	69	64	68	64	65
σ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

3 month $\bar{X}$ 64.5 σX)
6 month $\bar{X}$ 65.0 σX) - for all 5 runs
9 month $\bar{X}$ 64.3 σX)

TABLE IV (Cont'd) SLASH PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS LISTED BENEATH EACH SEED LOT

Seed Lot #17

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	100	100	100	90	100	100	100	100	100	90	90	95	85	85	90
	90	100	100	100	100	100	95	100	100	95	95	95	100	100	100
	-	-	-	90	100	100	100	100	100	100	100	100	85	90	90
	-	-	-	-	-	-	95	95	95	95	100	100	70	90	100
	-	-	-	-	-	-	90	90	90	75	80	80	90	100	100
$\bar{X}$	95	100	100	93	100	100	96	97	97	91	93	94	86	95	96
σ	7.1	0.0	0.0	5.8	0.0	0.0	4.2	4.5	4.5	9.6	8.4	8.2	10.8	5.0	5.5

3 month $\bar{X}$ 91.8 σ 4.0
6 month $\bar{X}$ 96.3 σ 3.1
9 month $\bar{X}$ 96.8 σ 2.6

Seed Lot #18

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	90	95	100	80	85	80	95	100	100	90	95	90	70	90	90
	55	60	60	85	85	90	35	55	55	55	89	89	80	90	95
	95	95	95	85	90	90	90	95	85	60	80	80	60	95	95
	70	80	90	95	95	95	95	100	95	63	95	79	70	85	85
	65	90	95	85	90	100	85	95	85	75	84	79	65	89	89
$\bar{X}$	75	84	88	86	89	91	80	89	84	69	89	83	69	90	91
σ	16.9	14.8	16.0	5.5	4.2	7.4	25.5	19.2	17.5	14.1	6.7	5.6	7.4	3.6	4.3

3 month $\bar{X}$ 75.7 σ 7.3
6 month $\bar{X}$ 88.1 σ 2.4
9 month $\bar{X}$ 87.4 σ 3.8

$\bar{X}$ Mean
σ Standard deviation
- Missing replicate
X Statistic not computed
* Mean and standard deviation of 5 runs

Seed lots 4 and 13 not included in statistical analysis.

TABLE IV(Cont'd) SLASH PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS LISTED BENEATH EACH SEED LOT

Seed Lot #5

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	90	95	90	95	95	100	100	100	100	100	100	95	95	95	95
	85	95	95	85	90	90	95	100	95	95	95	100	95	85	90
	95	95	95	90	100	100	100	100	100	95	100	95	100	100	100
	100	100	100	95	100	100	95	90	90	100	95	95	100	100	95
	90	100	95	95	100	100	100	100	100	85	90	95	90	100	100
$\bar{X}$	92	97	95	92	97	98	98	98	97	95	96	96	96	96	96
σ	5.7	2.7	3.5	4.5	4.5	4.5	2.7	4.5	1.1	6.1	4.2	2.2	4.2	6.5	4.1

3 month $\bar{X}$ 94.6 σ2.6)
6 month $\bar{X}$ 96.8 σ0.8) - for all 5 runs
9 month $\bar{X}$ 96.4 σ1.1)

Seed Lot #6

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	65	90	95	80	90	90	100	80	80	85	95	90	80	90	95
	80	95	90	80	90	90	95	95	95	85	90	90	65	70	70
	80	80	80	84	84	84	90	65	70	89	94	95	75	85	95
	75	85	85	90	100	100	90	85	95	85	100	100	75	79	79
	80	95	85	85	100	95	-	-	-	-	-	-	90	95	95
$\bar{X}$	76	89	87	84	93	92	94	81	85	86	95	94	77	84	87
σ	6.5	6.5	5.7	4.2	7.0	6.0	4.8	12.5	10.6	2.0	4.1	4.8	9.1	9.7	11.7

3 month $\bar{X}$ 82.7 σ7.3)
6 month $\bar{X}$ 88.3 σ5.9) - for all 5 runs
9 month $\bar{X}$ 97.8 σ1.3)

Seed Lot #7

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	85	100	100	90	95	95	100	100	100	95	100	95	100	100	100
	95	90	90	100	95	100	100	95	100	90	100	100	90	95	95
	100	100	100	100	100	100	95	94	95	100	100	100	90	100	100
	100	100	100	95	100	100	100	100	100	89	100	95	95	95	95
	90	90	95	95	95	100	100	100	100	80	95	90	89	100	100
$\bar{X}$	94	96	97	96	97	99	99	98	99	91	99	96	93	98	98
σ	6.5	5.5	4.5	4.2	2.7	2.2	2.2	3.0	2.2	7.5	2.2	4.2	4.7	2.7	2.0

3 month $\bar{X}$ 94.5 σ3.1)
6 month $\bar{X}$ 97.6 σ1.1) - for all 5 runs
9 month $\bar{X}$ 97.8 σ1.3)

Seed Lot #8

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	85	90	90	100	100	100	100	100	100	95	95	95	95	95	95
	95	95	95	95	95	95	90	85	90	90	95	95	95	95	90
	100	100	100	100	95	95	95	95	95	90	90	90	90	95	95
	90	100	100	100	100	100	100	100	100	100	100	100	80	90	95
	95	100	100	100	95	95	95	95	95	100	90	85	95	100	100
$\bar{X}$	93	97	97	99	97	97	96	95	96	95	94	93	91	95	95
σ	5.7	4.5	4.5	2.2	2.7	2.7	4.2	6.1	4.2	5.0	4.2	5.7	6.5	3.5	3.5

3 month $\bar{X}$ 94.8 σ3.0)
6 month $\bar{X}$ 95.6 σ1.3) - for all 5 runs
9 month $\bar{X}$ 95.6 σ1.6)

TABLE IV(Cont'd) SLASH PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS LISTED BENEATH EACH SEED LOT

Seed Lot #9

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	75	100	95	95	95	95	100	95	100	90	100	100	84	79	89
	85	95	95	95	95	100	90	90	95	100	100	90	89	89	95
	90	95	95	100	100	100	100	95	100	80	90	90	78	83	78
	95	95	95	90	90	95	100	95	95	90	100	100	75	95	95
	75	100	100	100	95	100	100	100	100	85	90	90	75	95	95
$\bar{X}$	84	97	96	96	95	98	98	95	98	89	96	94	80	88	90
σ	8.9	2.7	2.2	4.2	3.5	2.7	4.5	3.4	2.7	7.4	5.5	5.4	6.1	7.1	7.4

3 month $\bar{X}$ 89.4 σ7.7)
6 month $\bar{X}$ 94.2 σ3.6) - for all 5 runs
9 month $\bar{X}$ 95.3 σ3.3)

Seed Lot #10

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	95	95	100	95	100	100	95	95	95	84	95	100	75	90	100
	90	95	95	95	95	100	100	100	95	85	100	100	89	95	100
	95	100	100	85	95	100	95	100	100	85	95	95	85	100	100
	-	-	-	95	100	100	95	100	100	80	100	100	100	100	100
	-	-	-	85	90	90	85	100	100	95	100	100	65	89	95
$\bar{X}$	93	97	98	91	96	98	94	99	98	86	98	99	83	95	99
σ	2.9	2.9	2.9	5.5	4.2	4.5	5.5	2.2	2.7	5.5	2.7	2.2	13.4	5.3	2.2

3 month $\bar{X}$ 89.0 σ4.7)
6 month $\bar{X}$ 96.9 σ1.6) - for all 5 runs
9 month $\bar{X}$ 98.5 σ0.5)

Seed Lot #11

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	95	100	100	100	100	100	95	100	100	90	100	100	95	95	100
	100	100	100	95	100	100	95	100	100	100	100	100	100	100	100
	100	100	100	100	100	95	100	100	100	95	100	100	95	100	100
	90	95	95	100	90	90	90	90	90	95	100	100	95	95	95
	-	-	-	100	100	100	100	100	100	95	100	100	90	90	95
$\bar{X}$	96	99	99	99	98	97	96	98	98	95	100	100	95	96	98
σ	4.8	2.5	2.5	2.2	4.5	4.5	4.2	4.5	4.5	3.5	0.0	0.0	3.5	4.2	2.7

3 month $\bar{X}$ 96.3 σ1.6)
6 month $\bar{X}$ 98.1 σ1.5) - for all 5 runs
9 month $\bar{X}$ 98.3 σ1.1)

Seed Lot #12

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100
	90	95	100	100	100	100	100	100	100	95	100	100	85	100	95
	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100
	100	100	100	100	100	100	100	100	100	100	100	94	100	100	100
	95	95	95	95	100	100	100	100	100	90	100	100	95	100	100
$\bar{X}$	97	98	99	99	100	100	100	100	100	94	100	99	96	100	99
σ	4.5	2.7	2.2	2.2	0.0	0.0	0.0	0.0	0.0	4.2	0.0	2.2	6.2	0.0	2.2

3 month $\bar{X}$ 97.2 σ 2.4)
6 month $\bar{X}$ 99.6 σ 0.9) - for all 5 runs
9 month $\bar{X}$ 99.4 σ 0.5)

TABLE IV (Cont'd) SLASH PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS LISTED BENEATH EACH SEED LOT

Seed Lot #13

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	-	-	-	-	-	-	95	100	100	100	100	100	75	100	100
	-	-	-	-	-	-	83	100	88	65	100	100	95	100	100
	-	-	-	-	-	-	-	-	-	80	100	95	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$\bar{X}$	-	-	-	-	-	-	89	100	94	82	100	98	85	100	100
σ	-	-	-	-	-	-	X	X	X	X	X	X	X	X	X

3 month $\bar{X}$ 85.3 σ X)
6 month $\bar{X}$ 100 σ X) - for all 5 runs
9 month $\bar{X}$ 97.3 σ X)

Seed Lot #14

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	100	100	100	100	100	100	90	95	85	100	100	100	100	100	100
	100	100	100	90	95	90	100	100	100	85	100	95	90	95	95
	100	100	100	90	95	95	100	100	100	90	100	100	90	95	100
	90	90	90	100	100	100	100	100	100	90	95	95	95	100	100
	90	90	90	100	100	100	95	100	100	90	100	95	90	95	95
$\bar{X}$	96	96	96	96	98	97	97	99	97	91	99	97	93	97	98
σ	5.5	5.5	5.5	5.5	2.7	4.5	4.5	2.2	6.7	5.5	2.2	2.7	4.5	2.7	2.7

3 month $\bar{X}$ 94.6 σ 2.5)
6 month $\bar{X}$ 97.8 σ 1.3) - for all 5 runs
9 month $\bar{X}$ 97.0 σ 0.7)

Seed Lot #15

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	95	95	95	100	100	100	100	100	100	100	100	100	85	90	90
	90	90	95	90	90	90	95	95	95	89	94	94	90	90	90
	100	100	100	95	100	100	95	100	95	94	100	100	90	100	100
	89	95	95	100	100	100	95	95	95	88	100	100	85	100	100
	94	100	100	-	-	-	90	95	95	-	-	-	85	95	100
$\bar{X}$	94	96	97	96	98	98	95	97	96	93	98	98	87	95	96
σ	4.4	4.2	2.7	4.8	5.0	5.0	3.5	2.7	2.2	5.5	2.6	2.6	2.4	5.0	5.5

3 month $\bar{X}$ 92.8 σ 3.5)
6 month $\bar{X}$ 96.7 σ 1.3) - for all 5 runs
9 month $\bar{X}$ 96.9 σ 1.3)

Seed Lot #16

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	75	75	75	68	79	84	60	75	60	60	95	90	65	75	80
	80	90	85	75	75	75	60	75	75	65	75	80	50	56	61
	70	75	85	55	72	67	45	70	65	65	85	90	55	65	85
	-	-	-	-	-	-	74	84	89	65	80	90	63	89	89
	-	-	-	-	-	-	70	85	85	68	89	95	47	68	68
$\bar{X}$	75	80	82	66	75	75	62	78	75	65	85	89	56	71	77
σ	5.0	8.6	5.7	10.1	3.5	8.5	11.2	6.5	12.4	2.9	7.7	5.4	7.9	12.3	11.8

3 month $\bar{X}$ 63.6 σ 6.9)
6 month $\bar{X}$ 77.7 σ 5.3) - for all 5 runs
9 month $\bar{X}$ 79.7 σ 6.0)

TABLE V LOBLOLLY PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #19

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
60	65	65	60	65	65	80	80	70	80	80	75	80	80	80
90	90	90	70	75	80	62	92	92	90	80	80	70	75	75
90	80	85	85	85	84	-	-	-	80	80	80	65	65	60
75	85	90	45	60	65	-	-	-	69	88	75	-	-	-
-	-	-	60	50	65	-	-	-	-	-	-	-	-	-
$\bar{X}$ 79	80	83	64	67	72	71	86	81	80	82	78	72	73	72
$\sigma_{\bar{X}}$ X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

3 month $\bar{X}$ 73.2 $\sigma_{\bar{X}}$)
6 month $\bar{X}$ 77.6 $\sigma_{\bar{X}}$) - for all 5 runs
9 month $\bar{X}$ 77.2 $\sigma_{\bar{X}}$)

Seed Lot #20

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
85	100	100	65	70	90	80	95	95	90	100	100	-	-	-
75	100	100	65	85	100	70	100	90	95	100	100	-	-	-
85	90	90	95	90	95	85	100	100	80	95	95	-	-	-
70	100	100	90	90	95	70	90	90	95	100	100	-	-	-
67	87	93	85	90	95	-	100	100	-	-	-	-	-	-
$\bar{X}$ 76	95	97	80	85	95	76	97	95	90	99	99	-	-	-
$\sigma_{\bar{X}}$ X	X	X	X	X	X	X	X	X	X	X	X	-	-	-

3 month $\bar{X}$ 80.5 $\sigma_{\bar{X}}$)
6 month $\bar{X}$ 94.0 $\sigma_{\bar{X}}$) - for all 5 runs
9 month $\bar{X}$ 97.0 $\sigma_{\bar{X}}$)

Seed Lot #21

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
80	85	90	60	75	80	55	65	55	90	95	95	80	85	85
90	80	90	90	85	90	90	80	80	89	89	89	40	75	65
80	75	75	95	95	95	35	80	80	90	90	90	80	85	90
80	70	80	90	95	95	100	90	90	74	89	89	85	85	85
63	84	85	80	80	90	90	80	75	-	-	-	60	60	65
$\bar{X}$ 79	79	84	83	86	90	74	79	76	86	91	91	69	78	78
o 9.7	6.3	6.5	14.0	8.9	6.1	27.8	8.9	12.9	7.9	2.9	2.9	18.8	11.0	12.0

3 month $\bar{X}$ 77.8 σ 6.8)
6 month $\bar{X}$ 82.6 σ 5.6) - for all 5 runs
9 month $\bar{X}$ 83.5 σ 6.8)

Seed Lot #22

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
70	80	85	80	90	100	90	95	95	90	95	100	80	90	80
90	90	90	50	90	90	80	90	90	85	90	90	85	90	90
90	95	95	80	90	90	50	80	80	85	90	100	70	85	85
100	100	100	50	75	85	90	85	85	90	95	95	65	85	85
65	65	85	55	85	90	90	95	95	85	80	85	60	80	80
$\bar{X}$ 83	86	91	63	86	91	80	89	89	87	90	94	72	86	84
o 14.8	13.9	6.5	15.7	6.5	5.4	17.3	6.5	6.5	2.7	6.1	6.5	10.4	4.2	4.2

3 month $\bar{X}$ 77.0 σ 9.5)
6 month $\bar{X}$ 87.4 σ 1.9) - for all 5 runs
9 month $\bar{X}$ 89.8 σ 3.7)

TABLE V (Cont'd) LOBLOLLY PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #23

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	95	95	95	89	95	95	85	95	85	100	100	100	95	90	95
	100	100	100	55	90	95	85	90	90	85	95	95	75	95	95
	90	90	90	65	80	80	75	85	85	95	90	90	85	95	95
	74	84	84	95	95	95	90	95	95	85	90	85	-	-	-
	85	95	95	55	80	85	100	100	100	-	-	-	-	-	-
$\bar{X}$	91	93	93	71	88	90	87	93	91	91	94	93	85	93	95
σ	10.0	6.1	6.1	18.2	7.6	7.1	9.1	5.7	6.5	7.5	4.8	6.4	10.0	2.0	0.0

3 month $\bar{X}$ 84.7 σ 8.3)
6 month $\bar{X}$ 92.2 σ 2.4) - for all 5 runs
9 month $\bar{X}$ 92.0 σ 1.9)

Seed Lot #24

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	75	80	80	89	89	95	75	90	95	89	95	95	80	90	85
	78	94	88	75	70	75	85	85	80	90	95	100	75	85	80
	90	95	95	95	95	100	85	90	90	74	74	79	80	90	89
	-	-	-	90	95	95	95	95	95	80	90	90	80	85	85
	-	-	-	70	85	85	65	65	60	70	90	95	90	95	95
$\bar{X}$	81	90	88	84	87	90	81	85	84	81	89	92	81	89	87
σ	7.9	8.4	7.5	10.7	10.3	10.0	11.4	11.7	14.7	8.9	8.6	7.9	5.5	4.2	5.6

3 month $\bar{X}$ 82.0 σ 1.3)
6 month $\bar{X}$ 88.0 σ 2.0) - for all 5 runs
9 month $\bar{X}$ 88.1 σ 3.0)

Seed Lot #25

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	75	70	75	90	90	90	84	94	95	90	95	95	85	100	95
	65	85	90	75	85	85	60	90	90	90	95	100	75	95	100
	80	95	100	95	95	95	85	90	90	50	85	85	90	85	85
	90	85	90	90	90	90	100	100	100	65	75	75	85	100	100
	65	85	85	80	95	95	75	90	90	-	-	-	-	-	-
$\bar{X}$	75	84	88	86	91	91	81	93	93	74	88	89	84	95	95
σ	10.6	8.9	9.1	8.2	4.1	4.2	14.7	4.4	4.5	19.8	9.6	11.1	6.3	7.1	7.1

3 month $\bar{X}$ 80.0 σ 7.2)
6 month $\bar{X}$ 90.2 σ 4.3) - for all 5 runs
9 month $\bar{X}$ 91.1 σ 2.8)

Seed Lot #26

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	85	90	90	75	85	85	100	100	100	50	55	55	70	85	80
	90	90	90	85	90	95	70	90	85	90	95	95	95	100	100
	100	100	95	80	85	90	65	95	95	95	95	95	90	100	100
	85	95	95	90	95	95	70	85	85	65	75	80	95	95	90
	55	65	65	90	90	95	90	90	85	-	-	-	100	100	100
$\bar{X}$	83	88	87	84	89	92	79	92	90	75	80	81	90	96	94
σ	16.8	13.5	12.5	6.5	4.2	4.5	15.2	5.7	7.1	21.2	19.1	18.9	11.7	6.5	8.9

3 month $\bar{X}$ 82.5 σ 5.6)
6 month $\bar{X}$ 89.0 σ 5.9) - for all 5 runs
9 month $\bar{X}$ 89.2 σ 5.1)

TABLE V (Cont'd) LOBLOLLY PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #27

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	80	90	90	80	85	95	60	95	90	100	100	100	75	90	85
	70	85	85	55	90	100	85	95	95	95	95	95	100	100	100
	75	90	95	80	95	100	95	100	100	100	100	100	75	95	100
	90	100	100	90	90	95	75	95	95	70	85	85	89	95	95
	60	85	85	85	90	95	90	95	95	-	-	-	90	95	95
$\bar{X}$	75	90	91	78	90	97	81	96	95	91	95	95	86	95	95
σ	11.2	6.1	6.5	13.5	3.5	2.7	13.9	2.2	3.5	14.4	7.1	7.1	10.8	3.5	6.1

3 month $\bar{X}$ 81.8 σ 6.4)
6 month $\bar{X}$ 93.2 σ 2.9) - for all 5 runs
9 month $\bar{X}$ 94.5 σ 2.2)

Seed Lot #28

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	75	100	95	95	100	100	60	90	90	90	90	90	85	90	90
	95	95	95	95	95	95	95	100	100	85	90	90	95	100	100
	85	90	90	90	100	95	85	94	95	80	85	90	95	95	95
	70	95	95	90	95	95	80	100	95	80	90	90	75	74	79
	80	95	95	95	95	95	85	100	100	95	85	85	55	80	85
$\bar{X}$	81	95	94	93	97	96	81	97	96	86	88	89	81	88	90
σ	9.6	3.5	2.2	2.7	2.7	2.2	12.9	4.6	4.1	6.5	2.7	2.2	16.7	10.7	8.2

3 month $\bar{X}$ 84.4 σ 5.3)
6 month $\bar{X}$ 93.0 σ 4.6) - for all 5 runs
9 month $\bar{X}$ 93.0 σ 3.3)

Seed Lot #29

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	90	85	70	65	85	70	72	83	61	80	60	65	84	63	47
	84	89	74	65	60	45	78	95	84	65	53	53	75	80	65
	80	75	65	50	50	43	64	92	57	80	65	45	-	-	-
	65	63	56	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$\bar{X}$	80	78	66	60	65	53	71	90	67	75	59	54	80	72	56
σ	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

3 month $\bar{X}$ 73.2 σ X)
6 month $\bar{X}$ 72.8 σ X) - for all 5 runs
9 month $\bar{X}$ 59.2 σ X)

Seed Lot #30

	A			B			C			D			E		
	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
	100	100	100	85	90	95	80	95	95	90	80	85	100	95	95
	100	100	100	80	90	95	95	100	100	100	100	100	100	95	95
	95	95	95	85	95	95	90	95	95	85	90	95	90	95	100
	90	100	100	75	100	95	55	90	90	100	95	95	90	95	95
	95	95	95	-	-	-	80	95	95	85	85	90	90	100	100
$\bar{X}$	96	98	98	81	94	95	80	95	95	92	90	93	94	96	97
σ	4.2	2.7	2.7	4.8	4.8	0.0	15.4	3.5	3.5	7.6	7.9	5.7	5.5	1.0	2.7

3 month $\bar{X}$ 89.0 σ 7.5)
6 month $\bar{X}$ 94.6 σ 3.0) - for all 5 runs
9 month $\bar{X}$ 95.6 σ 1.9)

TABLE V (Cont'd) LOBLOLLY PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #31

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
100	100	100	75	95	100	65	70	75	70	70	70	85	90	95
95	95	95	65	85	85	65	85	85	55	65	65	85	95	95
80	90	90	70	85	85	55	95	90	70	85	80	89	94	94
70	85	85	35	70	65	60	90	90	70	75	75	85	100	95
80	90	95	85	95	95	55	90	80	65	70	70	95	95	95
$\bar{X}$ 85	92	93	66	86	86	60	86	84	66	73	72	88	95	95
σ 12.3	5.7	5.7	18.8	10.2	13.4	5.0	9.6	2.0	6.5	7.6	5.7	4.4	3.6	0.4

3 month $\bar{X}$ 73.0 σ 12.6)
6 month $\bar{X}$ 86.4 σ 8.4) - for all 5 runs
9 month $\bar{X}$ 86.0 σ 9.1)

Seed Lot #32

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
75	85	85	60	70	70	90	95	95	65	50	55	70	90	85
70	65	75	70	85	85	55	70	71	55	55	55	70	85	85
65	70	75	-	-	-	58	65	71	60	60	65	75	75	75
-	-	-	-	-	-	-	-	-	59	53	53	68	84	79
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$\bar{X}$ 70	73	78	65	78	78	68	76	80	60	55	57	71	84	81
σ X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

3 month $\bar{X}$ 66.8 σ X)
6 month $\bar{X}$ 73.2 σ X) - for all 5 runs
9 month $\bar{X}$ 74.8 σ X)

Seed Lot #33

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
75	70	70	45	45	50	70	50	50	55	55	40	80	75	75
95	89	79	50	40	35	55	60	60	70	55	55	85	75	65
65	65	60	60	60	65	65	65	65	60	45	40	85	90	65
65	70	65	95	95	60	75	55	55	80	55	55	85	85	60
75	65	70	55	65	50	70	80	65	90	55	45	85	65	50
$\bar{X}$ 75	72	69	61	61	52	67	62	59	71	53	47	84	78	63
σ 12.3	9.9	7.0	19.8	21.6	11.5	7.6	11.5	6.5	14.3	4.5	7.5	2.2	9.7	9.0

3 month $\bar{X}$ 71.6 σ 8.7)
6 month $\bar{X}$ 65.2 σ 9.8) - for all 5 runs
9 month $\bar{X}$ 58.0 σ 8.7)

Seed Lot #34

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
90	89	89	85	85	85	85	95	100	85	95	85	90	90	95
90	95	95	95	100	100	85	90	90	90	90	90	90	90	90
100	100	100	78	79	84	85	100	100	65	60	65	95	100	100
95	95	100	78	84	84	80	80	80	85	85	80	90	95	95
82	89	89	95	100	100	90	95	95	75	80	85	65	80	80
$\bar{X}$ 91	94	95	86	90	91	85	92	93	80	82	81	86	91	92
σ 6.7	4.7	5.5	8.5	9.8	8.6	3.5	7.6	8.3	10.0	13.5	9.6	11.9	7.4	7.6

3 month $\bar{X}$ 85.7 σ 3.9)
6 month $\bar{X}$ 89.8 σ 4.6) - for all 5 runs
9 month $\bar{X}$ 90.2 σ 5.4)

TABLE V (Cont'd) LOBLOLLY PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #35

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
50	55	60	30	70	65	47	74	74	70	60	70	80	80	85
60	70	80	65	70	70	85	85	85	70	80	75	45	50	55
65	75	75	85	85	85	80	80	80	65	65	65	74	68	63
70	75	80	-	-	-	66	80	73	55	55	60	40	50	47
75	75	70	-	-	-	-	-	-	-	-	-	55	60	60
$\bar{X}$ 64	70	73	60	75	73	69	80	78	65	65	68	59	62	62
σ 9.6	8.6	8.4	27.8	8.6	10.4	17.0	4.5	5.6	7.1	10.8	1.1	17.6	12.7	14.2

3 month $\bar{X}$ 63.4 σ 4.4)
6 month $\bar{X}$ 70.4 σ 7.3) - for all 5 runs
9 month $\bar{X}$ 70.3 σ 6.1)

Seed Lot #36

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
90	95	95	95	95	95	75	90	90	84	100	89	95	100	100
95	95	100	90	90	90	100	100	100	90	95	90	85	100	100
95	100	95	94	100	94	90	100	95	80	85	85	90	90	95
85	95	95	100	100	100	90	85	90	85	85	90	95	100	95
94	94	94	100	94	100	-	-	-	55	55	55	75	90	90
$\bar{X}$ 92	96	96	96	96	96	89	94	94	79	84	82	88	96	96
σ 4.3	2.4	2.4	4.3	4.3	4.3	10.3	7.5	4.7	13.7	17.5	15.1	8.4	15.1	4.2

3 month $\bar{X}$ 88.6 σ 6.3)
6 month $\bar{X}$ 90.4 σ 6.8) - for all 5 runs
9 month $\bar{X}$ 92.6 σ 6.0)

Seed Lot #37

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
50	65	65	50	60	50	80	85	75	55	55	60	45	40	45
65	75	75	45	65	65	53	100	68	60	70	60	65	70	70
45	65	75	40	50	50	33	66	61	60	55	50	50	58	63
60	65	65	60	80	70	90	95	95	35	25	20	55	75	65
53	61	61	40	60	40	50	70	65	25	40	40	60	70	70
$\bar{X}$ 55	66	68	47	63	55	61	83	73	47	49	46	55	63	63
σ 8.0	5.2	6.4	8.4	10.9	12.2	23.3	15.0	13.4	16.1	17.1	16.7	7.9	14.1	10.3

3 month $\bar{X}$ 53.0 σ 6.0)
6 month $\bar{X}$ 64.8 σ 12.1) - for all 5 runs
9 month $\bar{X}$ 60.9 σ 10.7)

Seed Lot #38

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
90	95	95	90	100	100	65	100	100	80	80	80	85	90	90
95	95	100	90	100	95	95	100	100	90	90	90	95	95	95
100	100	100	80	95	95	85	100	90	100	85	85	95	100	100
100	95	95	80	100	100	90	90	85	80	85	90	85	90	85
100	100	100	95	95	95	95	100	90	95	95	95	95	95	100
$\bar{X}$ 96	97	98	87	98	97	86	98	93	89	86	88	91	94	94
σ 4.5	2.7	2.7	6.8	2.7	2.7	12.5	4.5	6.7	8.9	5.7	5.7	5.5	4.2	6.5

3 month $\bar{X}$ 90.0 σ 4.4)
6 month $\bar{X}$ 94.8 σ 4.7) - for all 5 runs
9 month $\bar{X}$ 94.0 σ 3.9)

TABLE V (Cont'd) LOBLOLLY PINE DATA BY REPLICATE TRAYS
WITH RUN SUMMARYS* LISTED BENEATH EACH SEED LOT

Seed Lot #39

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
94	94	94	-	-	-	83	94	94	73	85	85	95	100	100
76	82	82	-	-	-	82	100	100	87	93	93	100	100	100
82	100	100	-	-	-	86	100	100	79	84	84	84	95	95
100	100	100	-	-	-	100	100	100	69	88	94	92	100	100
-	-	-	-	-	-	-	-	-	-	-	-	93	100	100
$\bar{X}$ 88	94	94	-	-	-	88	98	98	77	88	89	93	99	99
σ X	X	X	-	-	-	X	X	X	X	X	X	X	X	$\bar{X}$

3 month $\bar{X}$ 86.5 σ X)
6 month $\bar{X}$ 94.8 σ X) - for all 5 runs
9 month $\bar{X}$ 95.0 σ X)

Seed Lot #40

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
63	84	89	68	81	88	70	90	85	63	74	74	53	65	75
55	90	100	85	85	85	45	70	60	48	50	56	70	70	75
83	89	89	30	60	60	85	100	100	60	60	73	85	85	85
65	70	70	80	90	84	73	63	67	-	-	-	68	89	95
-	-	-	-	-	-	65	68	74	-	-	-	70	75	80
$\bar{X}$ 67	83	87	66	79	79	68	78	77	57	61	68	69	77	82
σ 11.8	9.2	12.4	24.9	13.2	12.9	14.6	15.9	15.7	7.9	12.1	10.1	11.3	10.1	8.4

3 month $\bar{X}$ 65.9 σ 4.8)
6 month $\bar{X}$ 75.6 σ 8.4) - for all 5 runs
9 month $\bar{X}$ 79.2 σ 7.0)

Seed Lot #41

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
80	85	85	100	100	100	70	75	75	60	65	70	83	94	100
60	85	85	90	90	95	75	80	80	75	75	80	85	85	85
90	95	95	70	80	80	75	90	90	80	85	85	65	75	80
90	90	90	85	95	95	80	80	80	90	90	90	90	95	95
95	95	95	85	85	90	55	85	90	90	90	90	75	85	80
$\bar{X}$ 83	90	90	86	90	92	71	82	83	79	81	83	80	87	88
σ 14.0	5.0	5.0	10.8	7.9	7.5	9.6	5.7	6.7	12.5	10.8	8.4	9.8	8.1	9.1

3 month $\bar{X}$ 79.7 σ 5.6)
6 month $\bar{X}$ 86.0 σ 4.3) - for all 5 runs
9 month $\bar{X}$ 87.2 σ 4.1)

Seed Lot #42

A			B			C			D			E		
3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
80	95	95	75	80	80	80	100	100	95	90	90	85	90	90
85	100	100	70	75	75	80	90	90	90	90	90	84	89	89
80	85	85	95	100	100	75	85	85	90	90	90	95	95	95
80	80	80	80	100	100	100	100	100	75	80	85	95	90	90
85	95	90	60	75	80	95	100	100	85	90	85	90	95	100
$\bar{X}$ 82	91	90	76	86	87	86	95	95	87	88	88	90	92	93
σ 2.7	8.2	7.9	12.9	12.9	12.1	10.8	7.1	7.1	7.6	4.5	2.7	5.3	2.9	4.6

3 month $\bar{X}$ 84.2 σ 5.4)
6 month $\bar{X}$ 90.4 σ 3.5) - for all 5 runs
9 month $\bar{X}$ 90.6 σ 3.3)

$\bar{X}$ Mean
σ Standard deviation
- Missing replicate
X Statistic not computed

*Mean and standard deviation

Seed lots 19, 20, 29, 32, and 39 not included in statistical analysis.

TABLE VI COMPARISON OF STANDARD DEVIATIONS WITHIN AND BETWEEN RUNS FOR THREE, SIX, AND NINE MONTHS READINGS

Seed Lot* Number	Mean of the Standard Deviations Between Replicate Trays Within Runs			Standard Deviation Between Run Means		
	3 mo.	6 mo.	9 mo.	3 mo.	6 mo.	9 mo.
Slash						
1	9.7	10.3	9.6	6.4	5.4	8.2
2	5.4	5.3	3.3	1.2	1.1	1.3
3	6.2	6.3	5.9	7.3	3.4	3.8
5	4.6	4.9	3.1	2.6	0.8	1.1
6	5.3	8.0	7.8	7.3	5.9	3.8
7	5.0	3.2	3.0	3.1	1.1	1.3
8	4.7	4.2	4.1	3.0	1.3	1.6
9	6.2	4.4	4.1	7.7	3.6	3.3
10	6.6	3.5	2.9	4.7	1.6	0.5
11	3.6	3.1	2.8	1.6	1.5	1.1
12	3.5	0.5	1.3	2.3	0.9	0.5
14	5.1	3.1	4.4	2.5	1.3	0.7
15	4.2	4.0	3.6	3.5	1.3	1.3
16	7.4	7.8	8.9	6.9	5.3	6.0
17	7.4	3.6	3.6	4.0	3.1	2.6
18	13.9	9.7	10.2	7.3	2.4	3.8
$\bar{X}$	6.2	5.1	4.9	4.5	2.5	2.6
Loblolly						
21	15.6	7.6	8.1	6.8	5.6	6.8
22	12.2	7.4	5.8	9.5	1.9	3.7
23	11.0	5.2	5.2	8.3	2.4	1.9
24	9.0	8.6	9.1	1.3	2.0	3.0
25	11.9	6.8	7.2	7.2	4.3	2.8
26	14.3	9.8	10.4	5.6	5.9	5.1
27	13.7	4.5	5.2	6.4	2.9	2.2
28	9.7	4.8	3.7	5.3	4.6	3.3
30	7.5	4.0	2.9	7.5	3.0	1.9
31	9.4	7.3	5.4	12.6	8.4	9.1
33	11.2	11.4	8.3	8.7	9.8	8.7
34	8.1	8.6	7.9	3.9	4.6	5.4
35	15.8	9.0	7.9	4.4	7.3	6.1
36	8.2	9.4	6.1	6.3	6.8	6.0
37	12.7	12.5	11.8	6.0	12.1	10.7
38	7.6	4.0	4.9	4.4	4.7	3.9
40	14.1	12.1	11.9	4.8	8.4	7.0
41	11.3	7.9	7.3	5.6	4.3	4.1
42	7.9	7.1	6.9	5.4	3.5	3.3
$\bar{X}$	11.1	7.8	7.1	6.3	5.4	5.0

* Seed lots 4, 13, 19, 20, 29, 32, and 39 not included in statistical analysis.